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# Characteristics analysis of high birefringence photonic crystal fiber with pentagonal air-core

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**Abstract. A** new type of photonic crystal fiber (PCF) with pentagonal air-core is proposed, which consists of octagonal air holes in the cladding. In addition, five elliptical air holes are embedded in the inner layer to enhance the birefringence characteristic. Characteristics of this PCF are analyzed by using of Finite Element Method (FEM). Numerical results show that this kind of PCF exhibits high birefringence with the level of $10^{-3}$ after optimization, which will find application in optical sensing systems.

## Introduction

Photonic crystal fibers (PCFs) are a new type of structure which has potential applications in optic-fiber communication and sensing systems because of their unique properties. For example, index guiding PCFs have gained great interest over the past years, and a great deal of investigation has been made to achieve high performance in optic-fiber systems. All solid total reflection PCFs with different structure have been analyzed by using Finite Element Method (FEM) and investigations show that these PCFs exhibit well properties in many aspects such as dispersion, nonlinear and birefringence [1-4].

Over the past few years, a great deal of attention has been focused on designing of PCF with different structure aiming at its outstanding properties. For example, Park et al. propose a new type of birefringence index guiding PCF with two hollow $GeO_2$-doped silica ring defects imbedded in a hexagonal hole arrays, and simulation results show that the birefringence of this type of PCF is flexibly controlled and independent of chromatic dispersion, in addition, improvement in confinement loss is also achieved by optimizing hollow ring defect parameters [5]. Zhang et al. investigate the polarization properties and propagation characteristics of polymer PCF with elliptical core and non-hexagonal symmetry structure by using the FEM. The results show that this PCF exhibit high birefringence and limited polarization mode dispersion characteristics, which operating in a single mode regime at an appropriate wavelength range after optimization [6]. Cheng et al. investigate the properties of light guiding mechanism and modes relating to the core refractive index in a hybrid PCF, which provide guidance for the design of hybrid PCF for special purposes in optic-fiber communications systems [7].

Nowadays, with the rapid development of technology and consummation of numeral analysis methods, accurate designing and analyzing PCF have become a reality in many aspects. Nowadays, designing PCF with high birefringence has become an important way to enhance the performance of systems. And, investigations show that PCF with mix-structure will enhance the characteristics of PCF by improving the dissymmetry of structure. In this paper, a high birefringence PCF with pentagonal air-core has been analyzed by using FEM [8]. Simulation results show that high birefringence with the level of $10^{-3}$ is obtained after optimization, which would be used in optic-fiber sensing systems such as optical fiber devices.

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**Designing of PCF and results analysis**

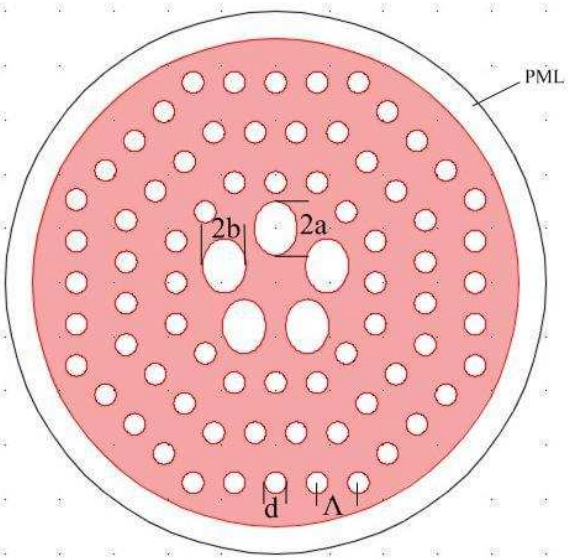
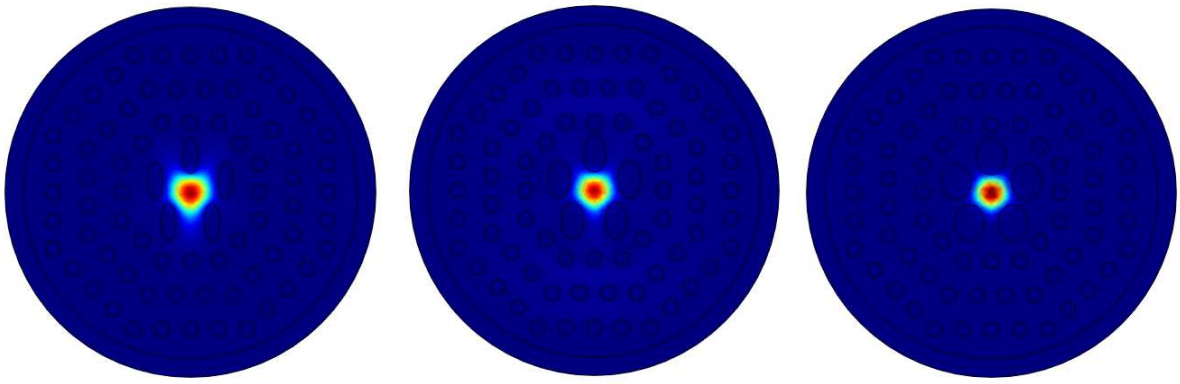



Fig. 1 Schematic of PCF with high birefringence and high nonlinearity

Fig. 1 shows the schematic of the proposed PCF, and there are four layers air holes, in which the inner layer is pentagonal elliptical air hole to enhance the birefringence characteristic. In this paper, we mainly analyze the characteristics of PCF by using of FEM accurately, and some of parameters are defined as follows: diameter of air holes $d = 0.8\mu m$, air holes pitch $\Lambda = 2\mu m$. And in the core, $2a$ and $2b$ are the major and minor axis of ellipse, where $\alpha = b/a$ is ellipticity, and $a = 1\mu m$.

**The flow of power.** Fig. 2 (a), (b) and (c) show the flow of power of proposed PCF at a given wavelength $\lambda = 1.55\mu m$ when ellipticity $\alpha = 0.4$, $\alpha = 0.6$ and $\alpha = 0.8$ respectively. From fig. 2, we can find that the power mainly concentrate on the center of the core, and with the increasing of $\alpha$, the power is compressed slowly, which exhibits well performance due to the concentration of power. This property will improve the whole performance of the systems. And in this paper, we mainly analyze the characteristics of x-polarization of $HE_{11}$ mode.



(a) $\alpha = 0.4$ (b) $\alpha = 0.6$ (c) $\alpha = 0.8$

Fig. 2 The flow of power of proposed PCF when wavelength $\lambda = 1.55\mu m$ with different $\alpha$.

**Effective refractive index.** Fig. 3 shows the effective refractive index as a function of wavelength with different ellipticity, from which we can find that effective refractive index decreases monotonously with the increasing of wavelength. It is also observed that the effective refractive index decreases with the increasing of ellipticity $\alpha$, which is due to the increasing of air-proportion in the cross-section of PCF.

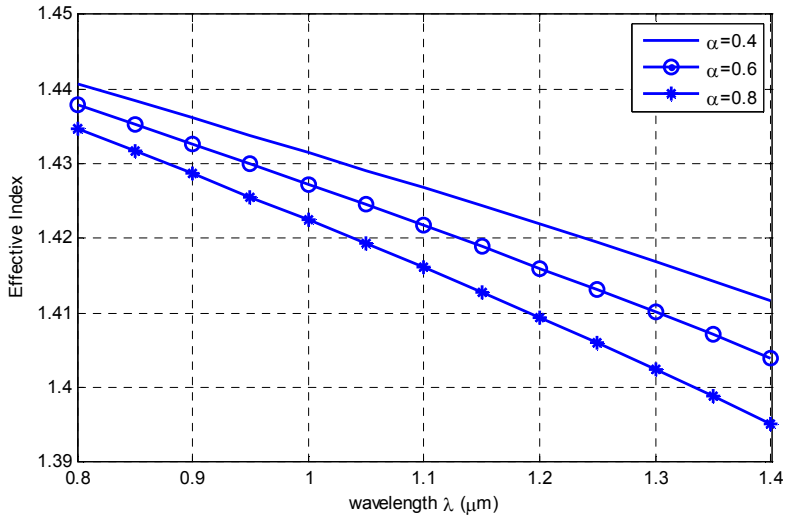



Fig. 3 Relationship of effective refractive index and wavelength with different ellipticity

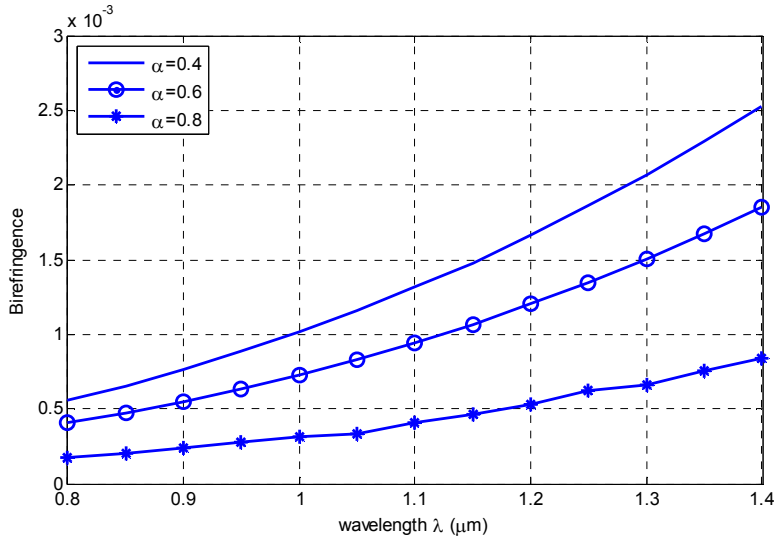



Fig. 4 Relationship of birefringence and wavelength with different ellipticity

**Birefringence.** Recent years, polarization characteristic of fiber plays a more and more important role in optic-fiber sensing and communication systems, so birefringence analysis of PCF has become an important way to further improve the performance of systems. In this paper, we also analyze the birefringence of the proposed PCF with different $\alpha$ thoroughly. Relationship between birefringence and wavelength with different $\alpha$ are shown in Fig. 4, from which we can find that this kind of PCF exhibits high birefringence with the level of $10^{-3}$, and fulfills the requirement of many applications. Simulations results show that the value of birefringence is higher than most of PCF and conventional fibers, which would exhibits higher polarization property, it is useful in optic-fiber sensing areas. In addition, from fig. 4, we can also observe that the birefringence increasing with the increasing of $\alpha$, which is because of the shift of dissymmetry.

## Summary

In conclusion, a new type of PCF with pentagonal air-core is proposed aiming at the requirement of high polarization in optic-fiber sensing system. The characteristics of PCF are investigated by using FEM, and simulation results show that this type of PCF exhibits high birefringence characteristic with the level of $10^{-3}$, which is higher than conventional fibers and many PCFs.

Investigations show that this high birefringence characteristic is mainly depend on the addition of five elliptical air holes in the inner cladding which lead to dissymmetry of structure. Therefore, this type of PCF would find applications in optic-fiber sensing and communication systems.

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